Particle Identification with DIRC

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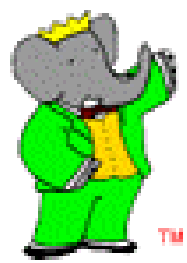
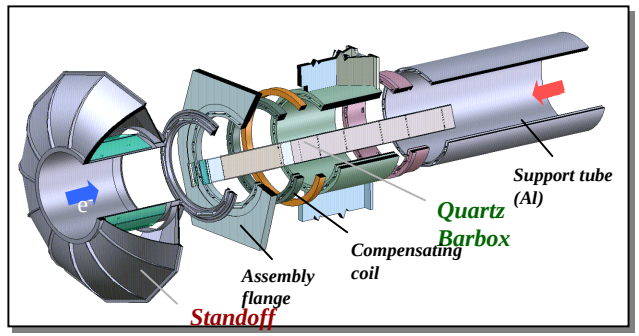
BaBar Collaboration

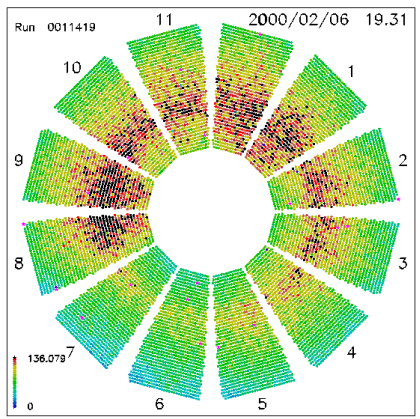


Major topics

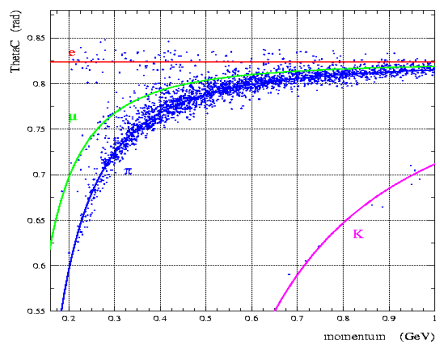
- ***Construction and design***



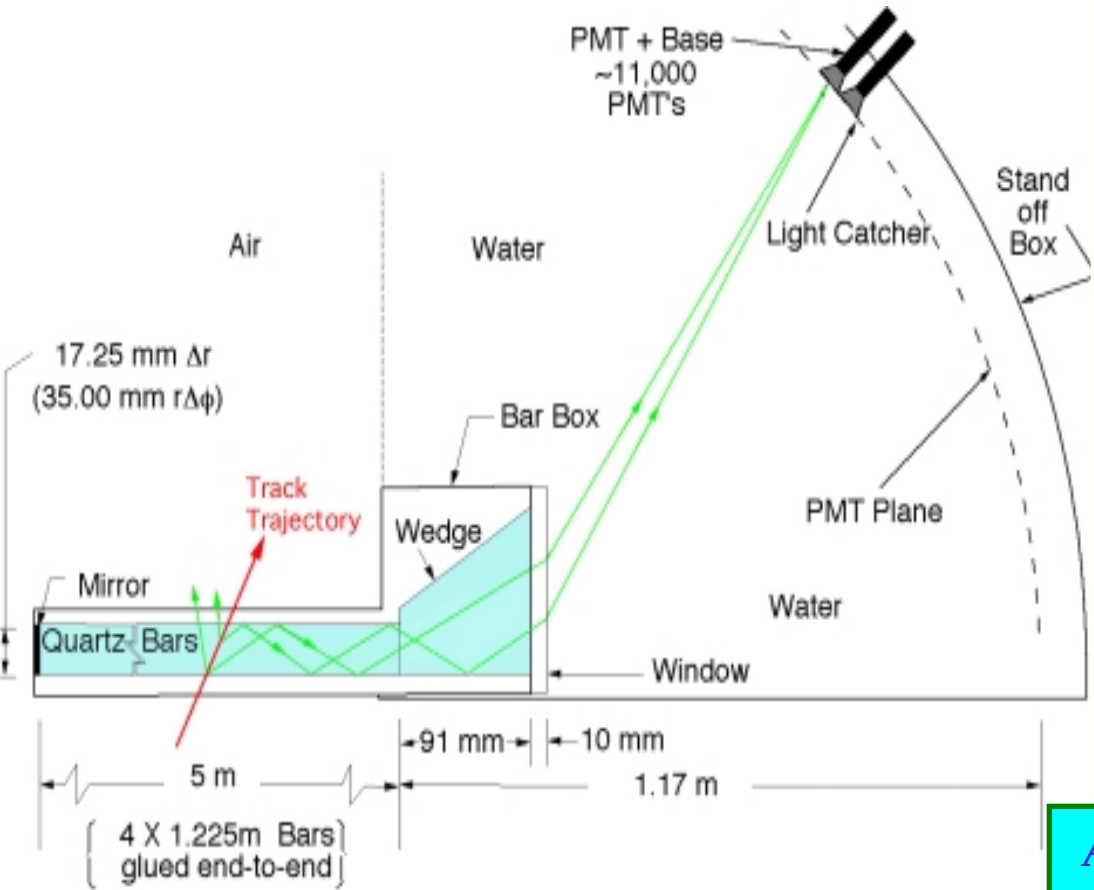
- ***Operations***

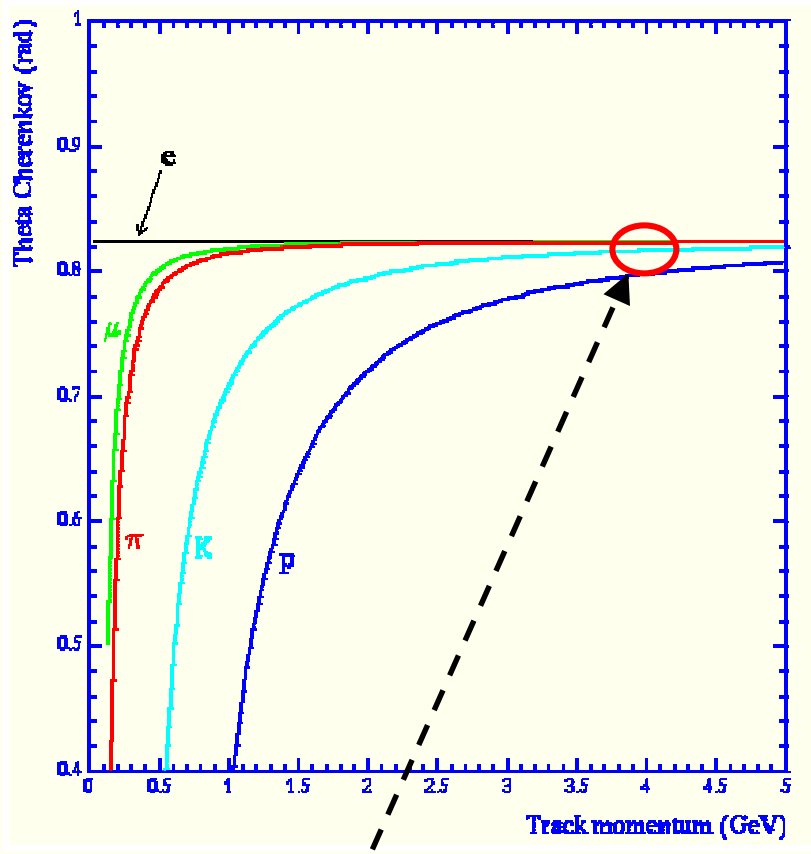


- ***Particle Identification***



Basic principles





At 4 GeV /c π and K are separated by ~6.4 mrad

~200-400 bounces with ~10-20% of photons lost depending on angle it takes ~10ns to ~60ns to travel inside the bars

DIRC is a 3D device

- ***DIRC is measuring photon arrival time at PMT position***

x_{PMT}, y_{PMT}, $t_{arrival}$ →

$$\cos\theta_C = 1/\beta n(\lambda)$$

$$\Delta t = t_{arrival} - t_{expected}$$

$$N_{photons} \sim L \sin^2\theta_C$$

consistency!

- ***expected uncertainties*** *(ideal detector and no background)*:

per photon:

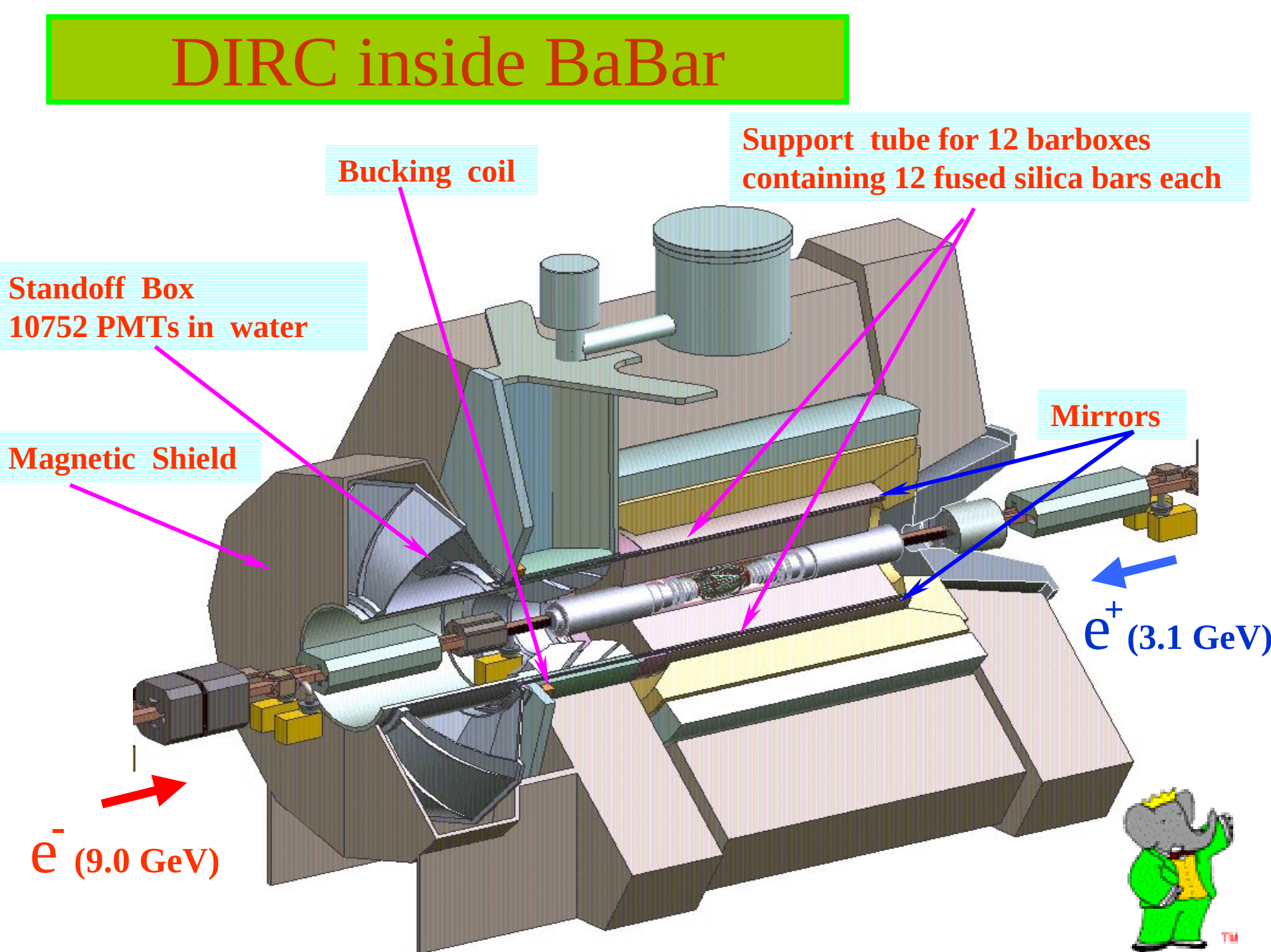
$$\Delta\theta^2_C = \Delta\theta^2_{C,track} + \Delta\theta^2_{C,dispersion} + \Delta\theta^2_{C,transport} + \Delta\theta^2_{C,imaging} + \Delta\theta^2 \sim (9.8\ \text{mrad})^2$$

~1 mrad; ~5.4 mrad; ~0.5 mrad; ~7.0 mrad (PMT diameter)

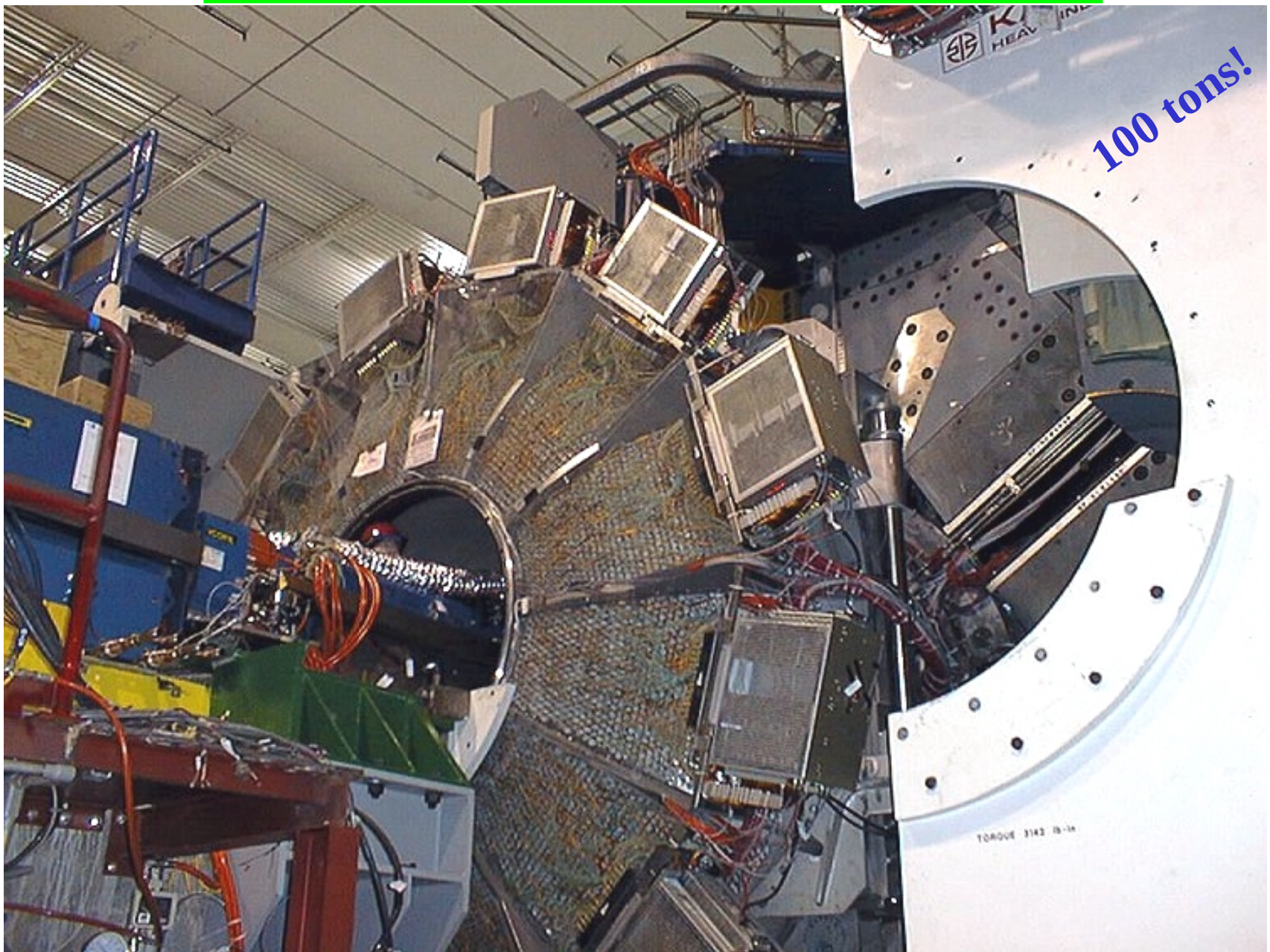
$$\Delta t^2 \sim \Delta t^2_{PMT} \sim (1.5\ \text{ns})^2$$

per track: $\Delta\theta^{track}_C \sim \Delta\theta^{photon}_C / \text{sqrt}(N_{photons\text{-}per\text{-}track})$, $N_{photons\text{-}per\text{-}track} \sim 30$

DIRC inside BaBar



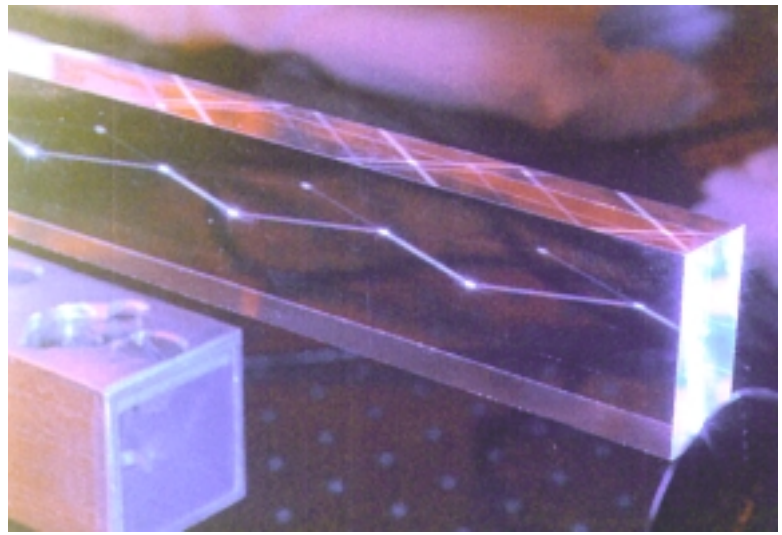
DIRC with open doors

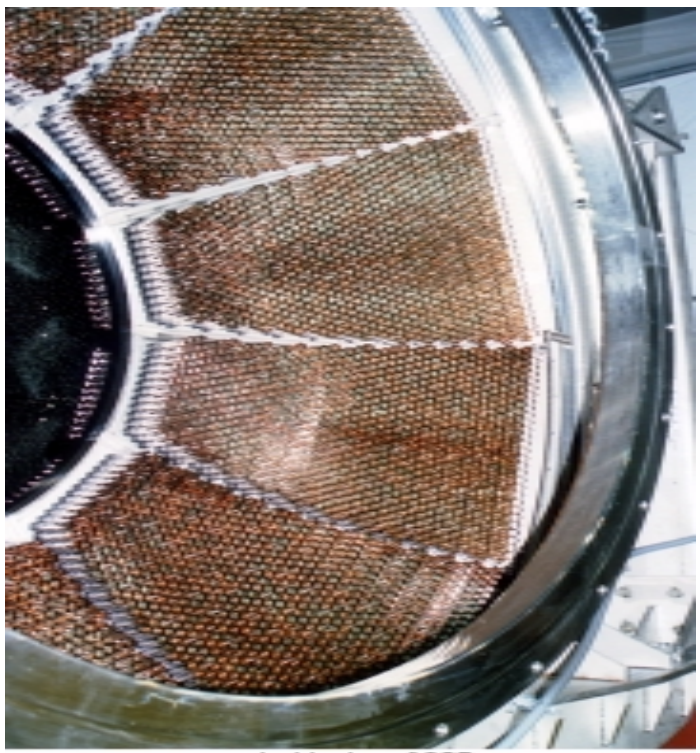


Major detection components

Radiator and light guide:

12 bar boxes with 144 4.9 meter long fused silica bars with n = 1.47, at 442nm bulk transmission is (99.9±0.1)%/m, surfaces reflectivity is (99.96±0.01)%
All bar boxes were installed by October 1999



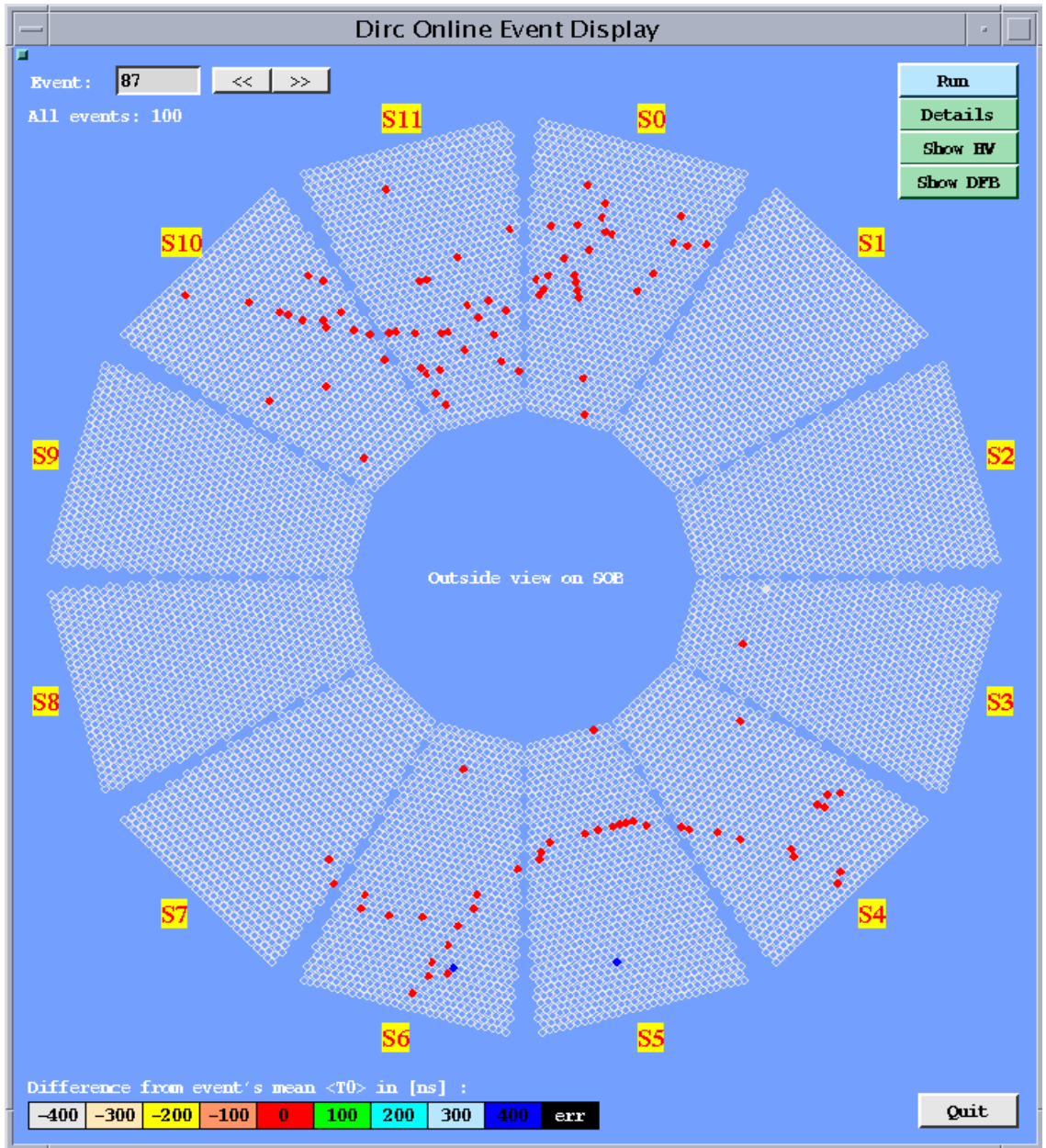


Stand Off Box with PMTs:

10752 ELT9125 phototubes(28mm diameter) with Rhodium coated plastic light catchers, 10^7 gain, 30% eff. at 442nm, time resolution is 1.5ns

after 1.5 years operations in water 99.63% PMTs are “alive and kicking”!!!

Event display



Major operations components

Life support systems:

- *DIRC HV and LV system*
- *water purification plant(transparency control)*
- *N_2 circulation and water leak detection system*
- *emergency water dump system*
- *CsI background sensors and shielding*

→ ***Integrated EPICS control and archiving*** → ***BaBar alarm handler***

DIRC DAQ:

- *12 VME crates, 168 DFBs, 12 DCCs,* **6 ROMs**

→ ***BaBar Dataflow system***

Data quality control:

- *fast monitoring(no reco)*
- *detailed monitoring(after reco)*
- *daily online calibrations*

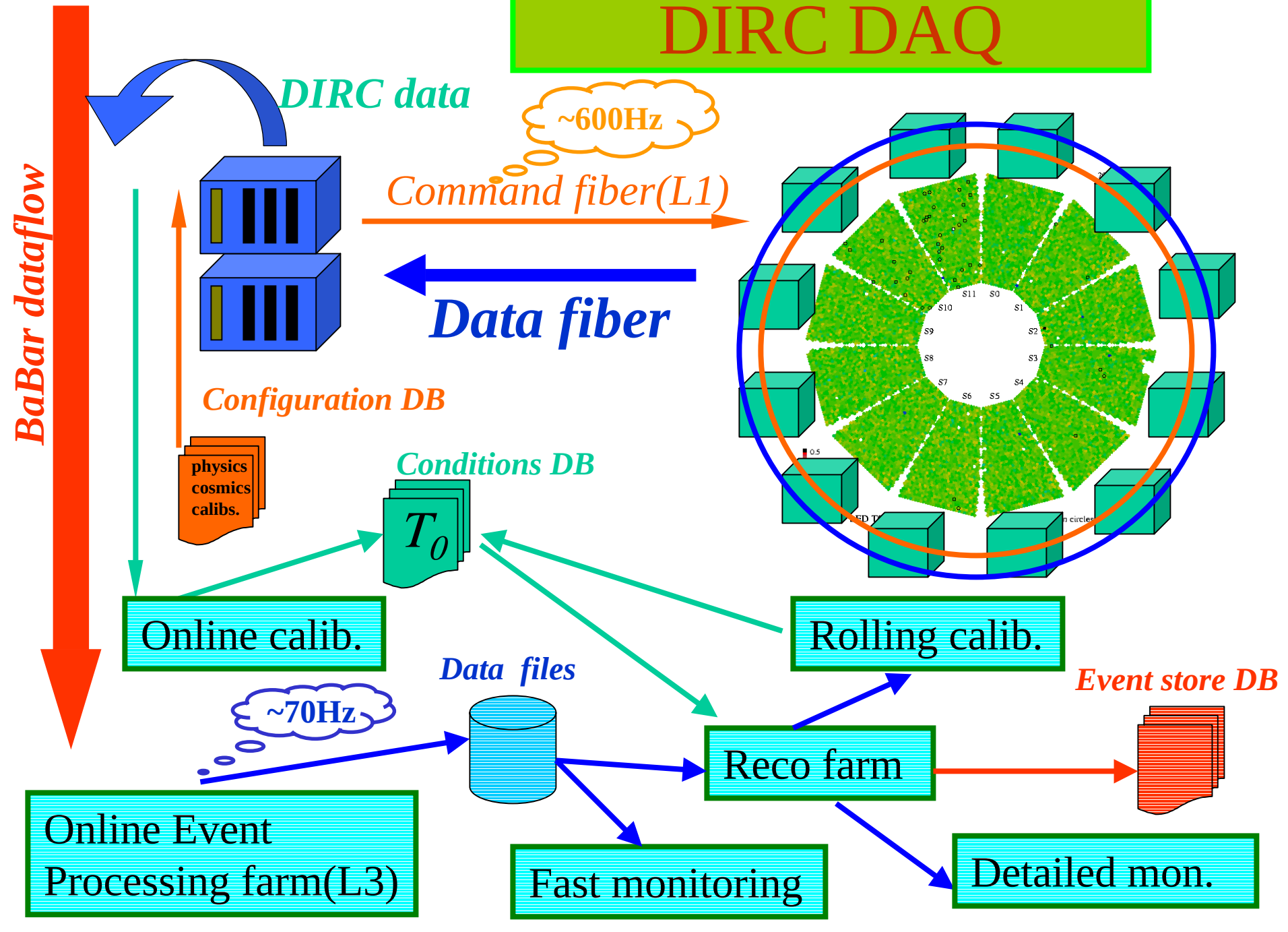
→

PID extraction:

- *timing & T_0 calibration constants*
- *alignment*
- *θ_c reconstruction algorithms*

DAQ+alarm handler + fast monitoring + online calibrations are done by BaBar shifters – no DIRC shifters on duty!

DIRC DAQ


BaBar dataflow
DIRC data
~600Hz
Command fiber(L1)
Data fiber
Configuration DB
physics
cosmics
calibs.
Conditions DB
T_0
Online calib.
Rolling calib.
Data files
~70Hz
Event store DB
Reco farm
Online Event
Processing farm(L3)
Fast monitoring
Detailed mon.

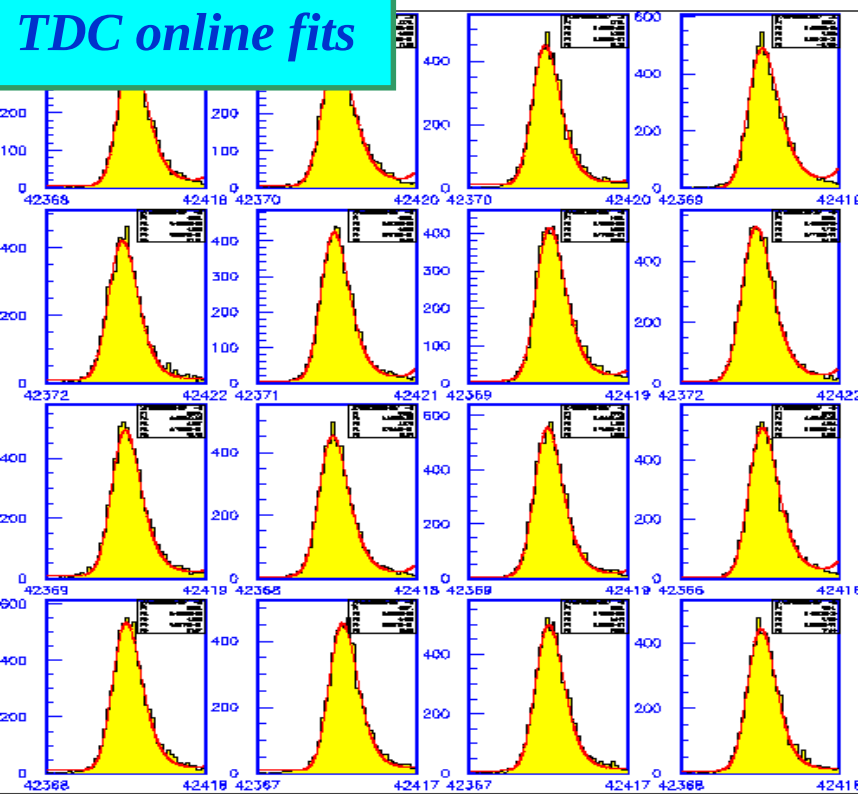
Online LED Calibrations

Using 12 LED light pulsers & 6 Power PC based ROMs, we do fast(daily 3-4 minutes) online calibrations of electronics gain, photon occupancy, TDC, and ADC spectra shapes. Fit parameters for each channel are stored in the Conditions DB and currently used for reconstruction

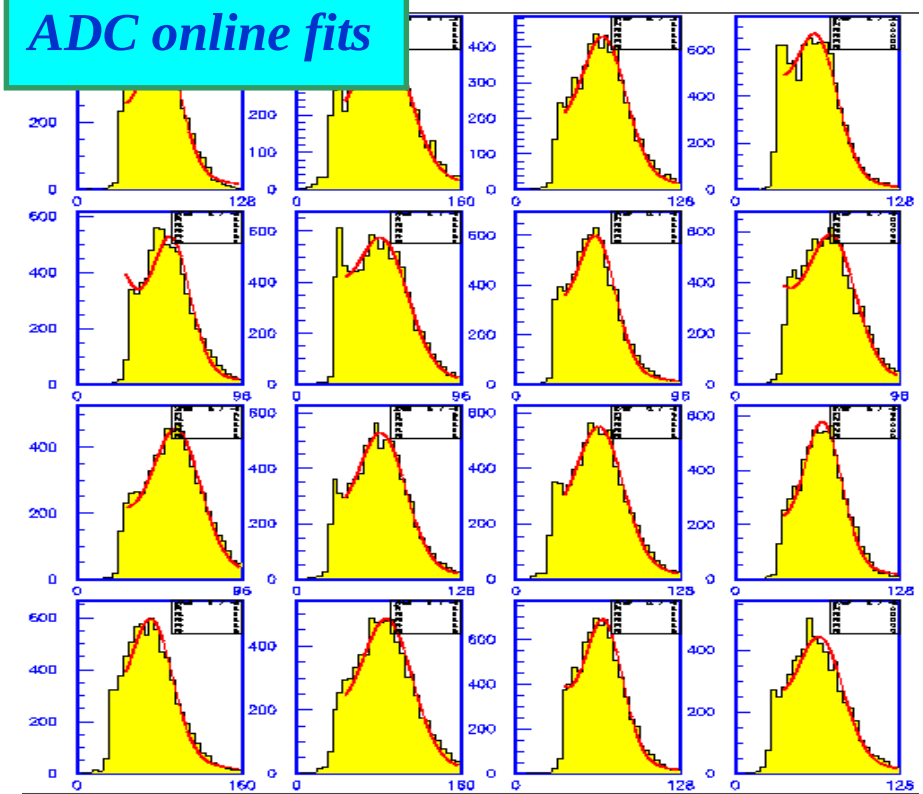
Offline Datastream Calibrations

Using reconstructed data accumulated over each ~20 hours time period of datataking one can fit photon time spectra extracting calibrations constants which lead to 10-15% improvement(over online T0s) in timing resolution. These "ultimate" T^0 constants will be used for reco. in the future.

TDC online fits

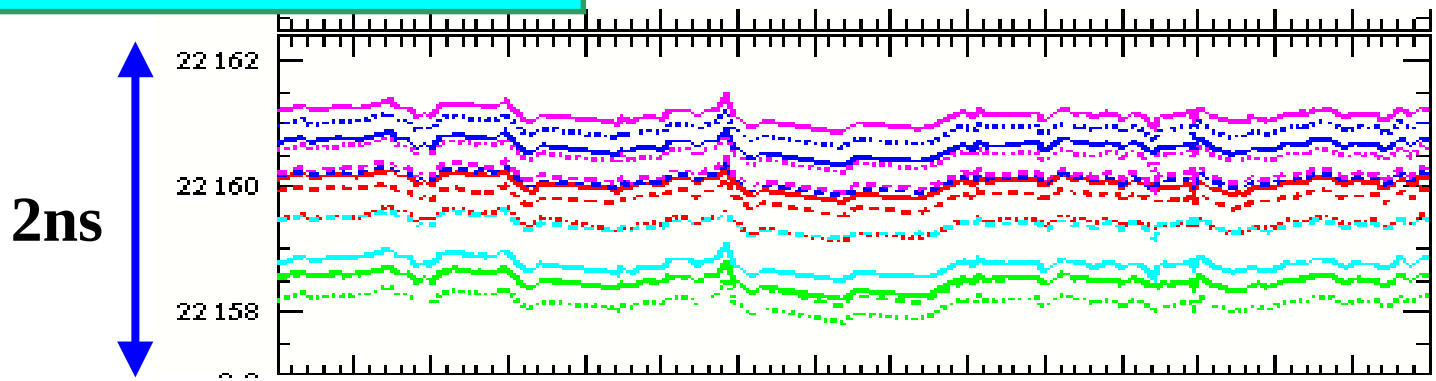


ADC online fits



Stability and importance of T0 calibrations

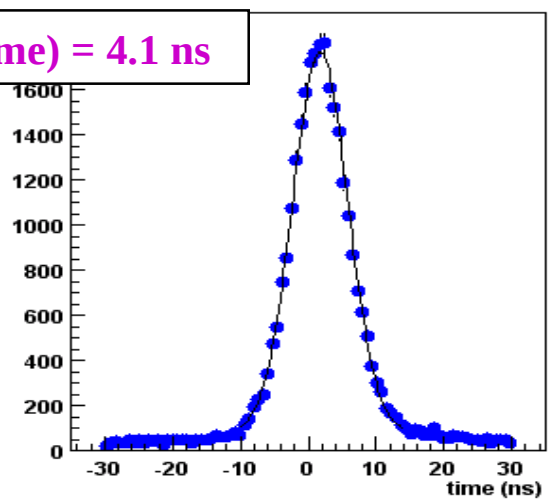
T^0 change in Sector 2 over 9 months...



August 1, 1999 ⟷ **May 10, 2000**

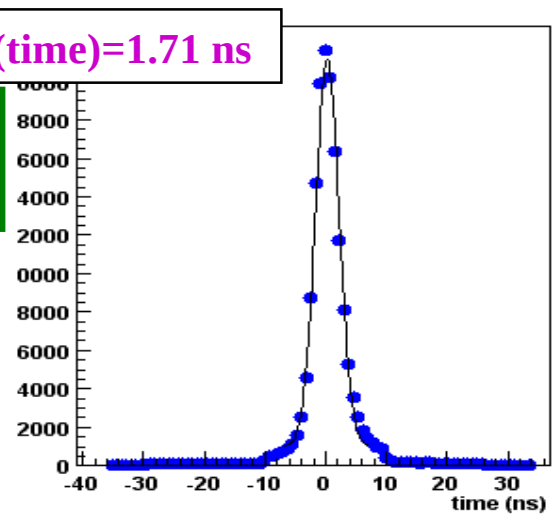
Photon time resolution before and after corrections

σ(time) = 4.1 ns

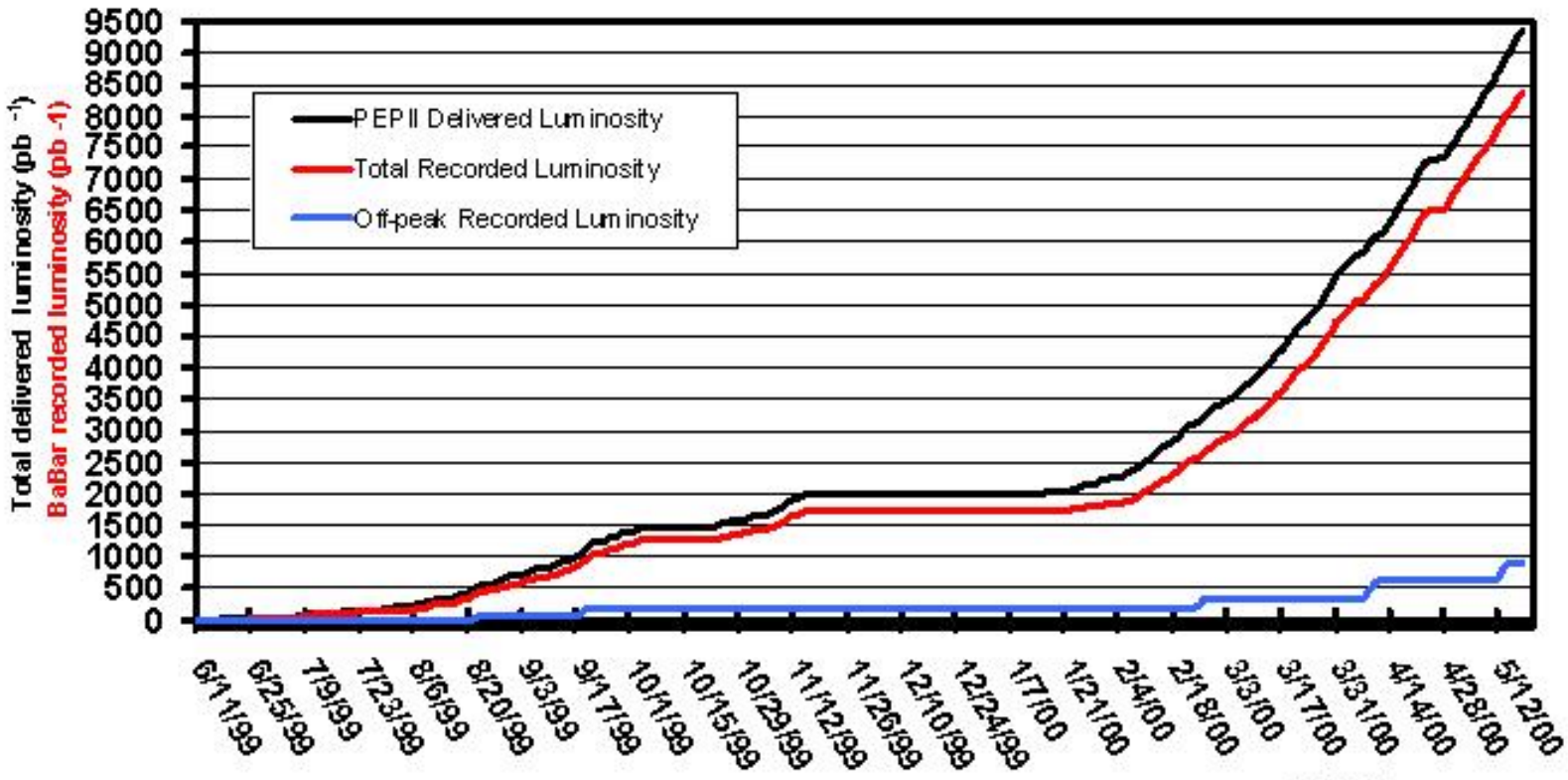


Event timing & T^0 calibrations

σ(time)=1.71 ns



PEPII luminosity



L1 trigger rate: ~600Khz, with 200ns jitter

L3 trigger rate: ~70Hz , raw event size: 25-30Kbytes

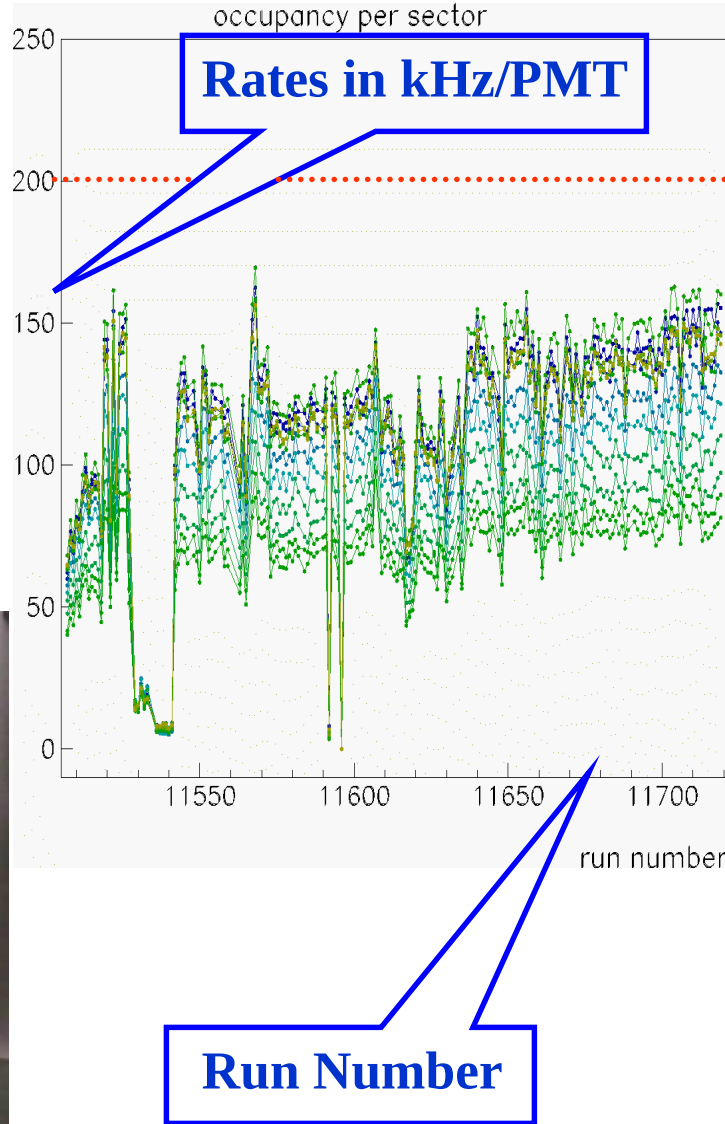
Bunch-to-bunch spacing: ~4.2 - 8.4ns

Peak Luminosity: ~**2x10^{33}** , datataking rate ~**100pb/day**

Background rates and monitoring

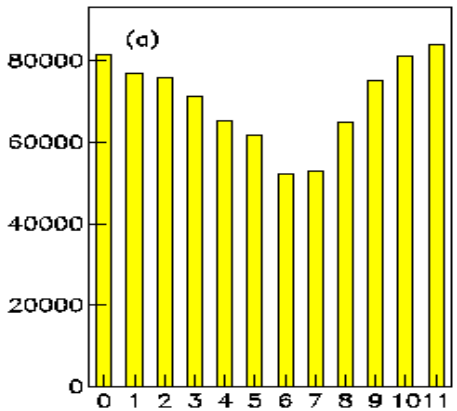
- rates above 200kHz per tube start causing FEE deadtime
- background rates are dominated by Low Energy Ring current and studied by an array of CsI sensors
- temporary shielding around Q4 magnet showed significant reduction of background levels
- permanent lead shielding is under construction

affects DAQ, not reconstruction!

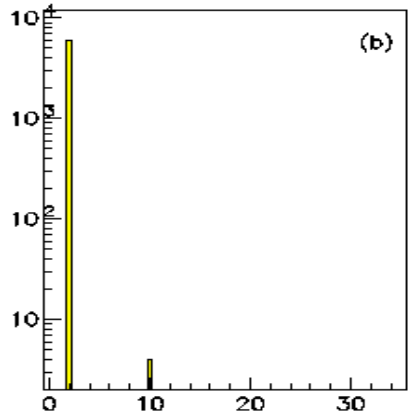


Fast Monitoring

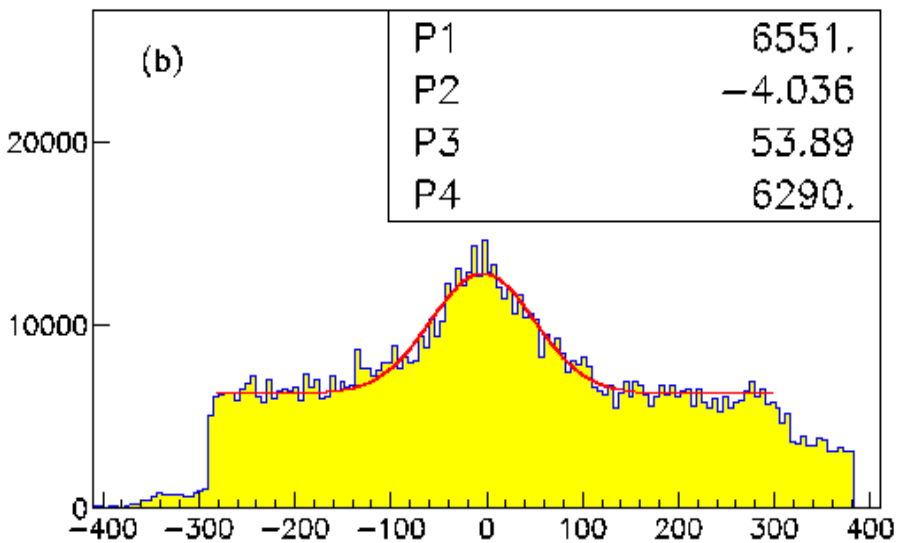
- continues monitoring of the data quality before reconstruction



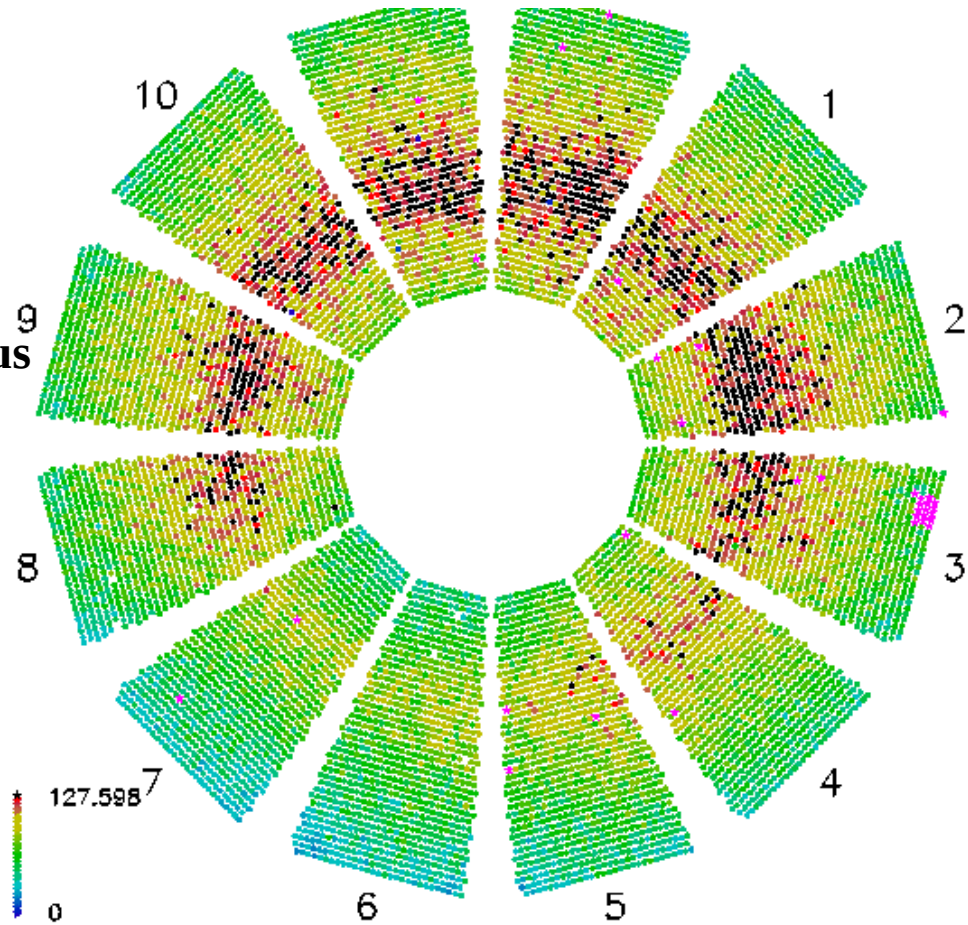
TDC hits per tube



Data extraction status

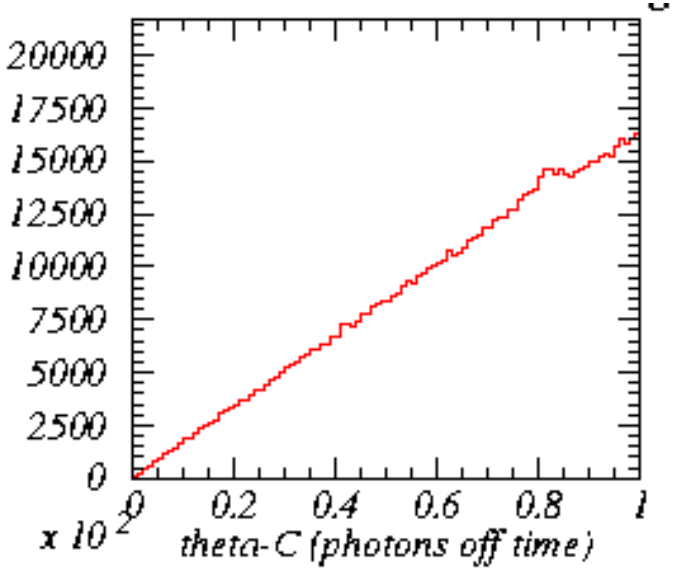


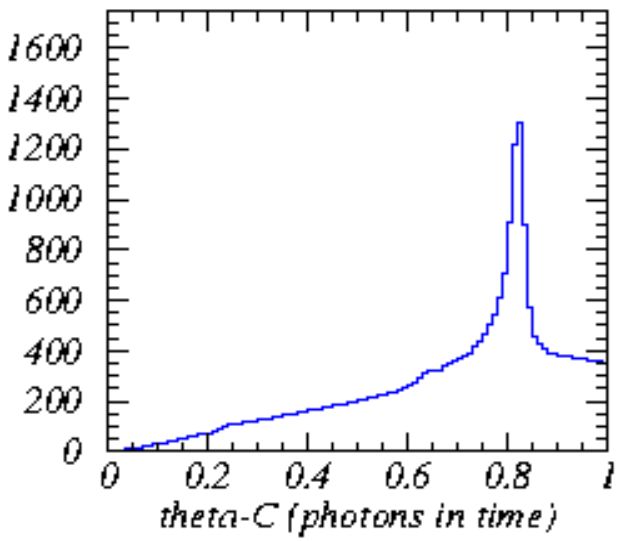
“photons arrival time” – “trigger time”, [ns]

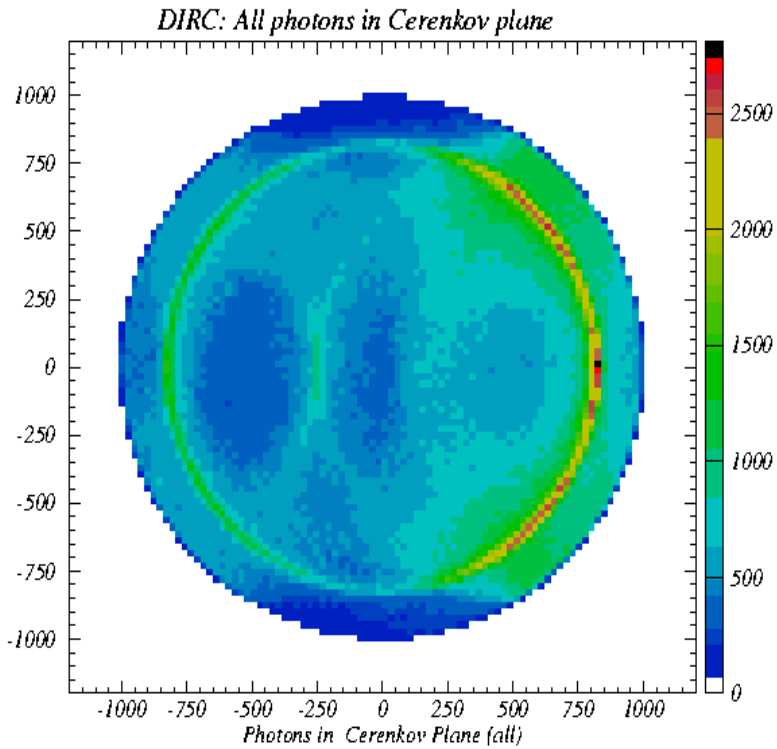


The hit frequency per phototube

Detailed Monitoring



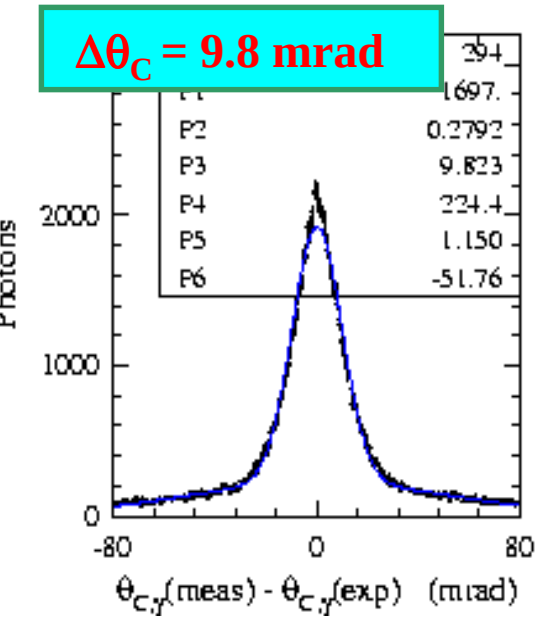




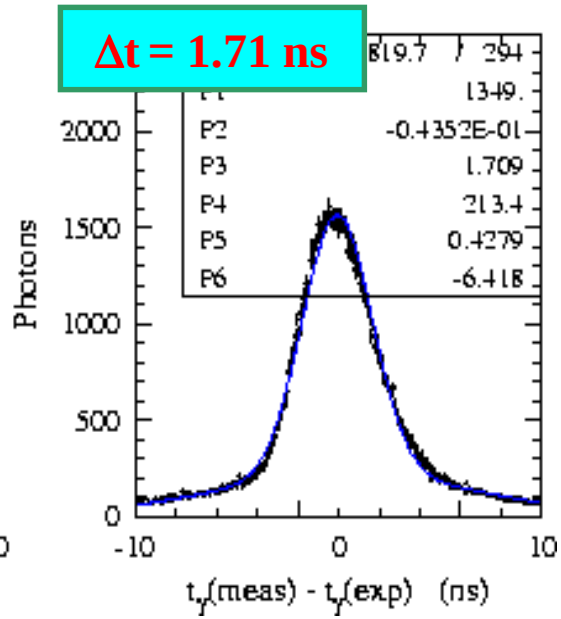
In this view, r is the Cerenkov angle of the photons, ϕ is the angle of the photons wrt the bar axis

Reconstruction

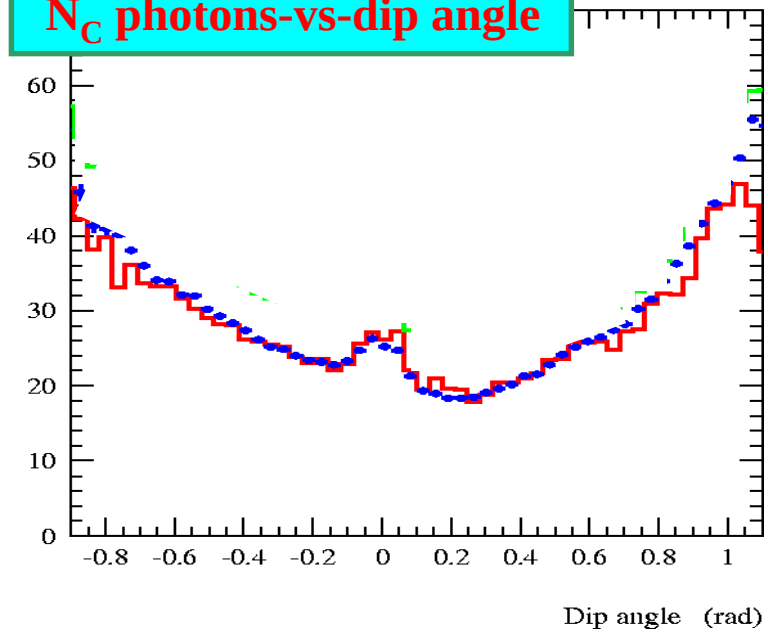
$\Delta\theta_C$ = 9.8 mrad



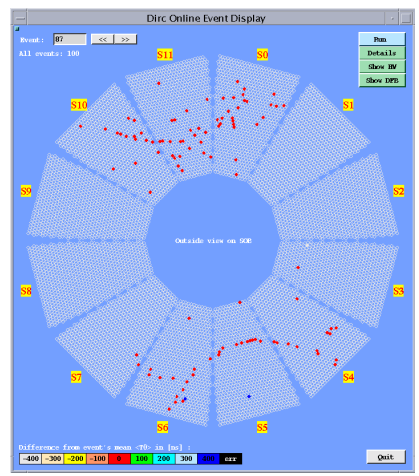
Δt = 1.71 ns



N_C photons-vs-dip angle



After we've "sharpened our weapons" we can try to reconstruct events:



Reconstruction Algorithm

• **Calculate unbiased likelihood for observed photons to originate from track or background: (Proba(θ_C), Proba(time), Proba(Nc));**

• **Provide likelihood, S/B for e/μ/π/K/p hypotheses**

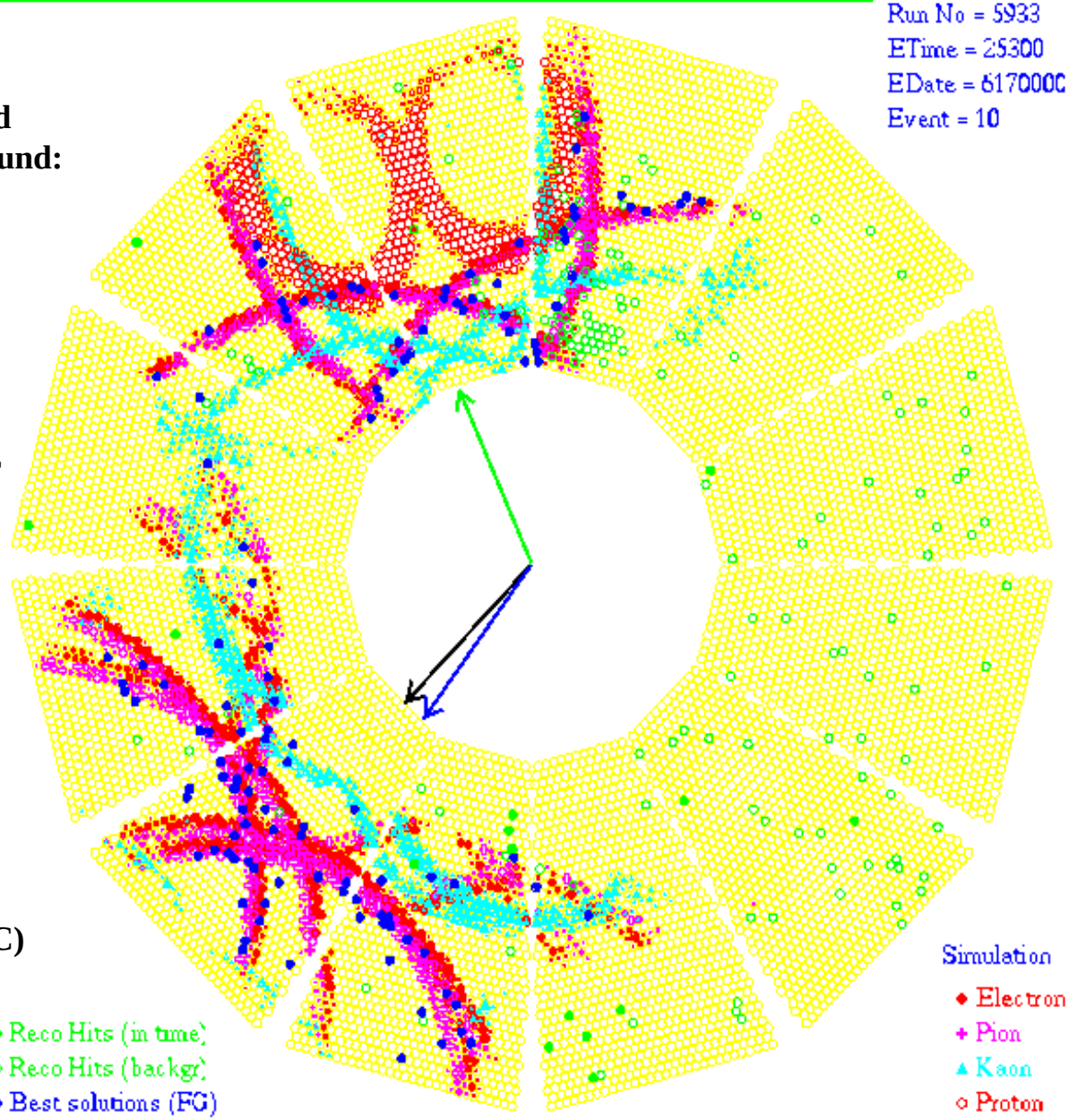
• **two main algoritms:**

1) GlobLikel

Global event likelihood calculated for entire event, iterative process, provides likelihood for 5 hypotheses for each track.

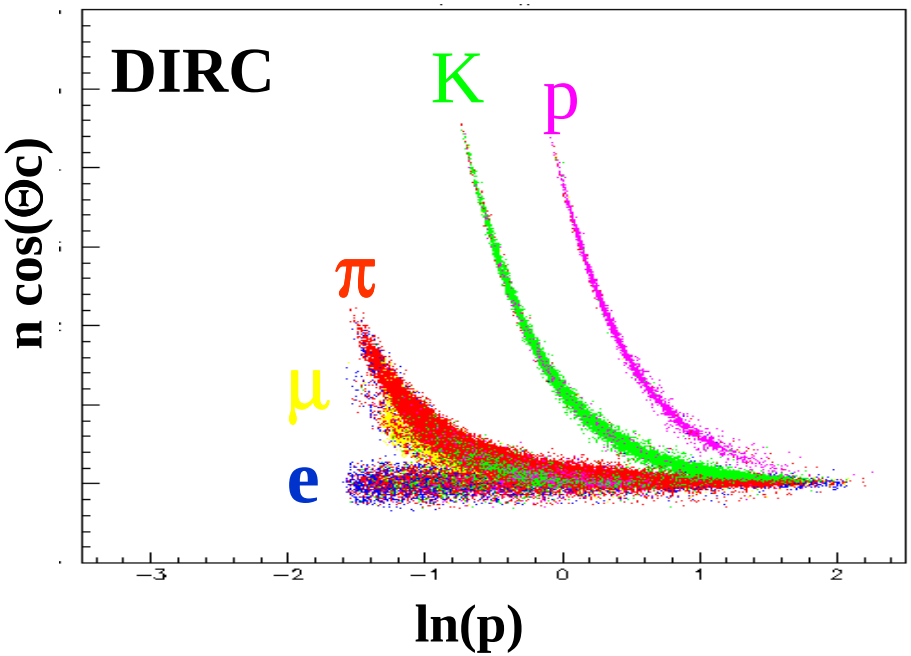
2) DrcMaxLikelihood

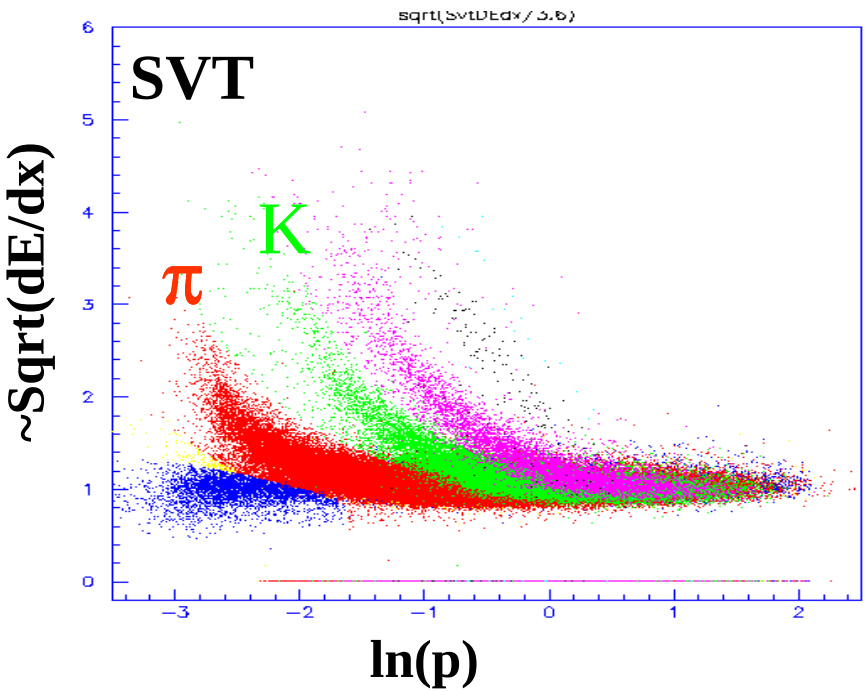
- Track based likelihood per track:
- θ_C,
- B/S ratio (yielding number of signal,
- background photons from the total number of associated photons)
- the track center coordinates (xC, yC)

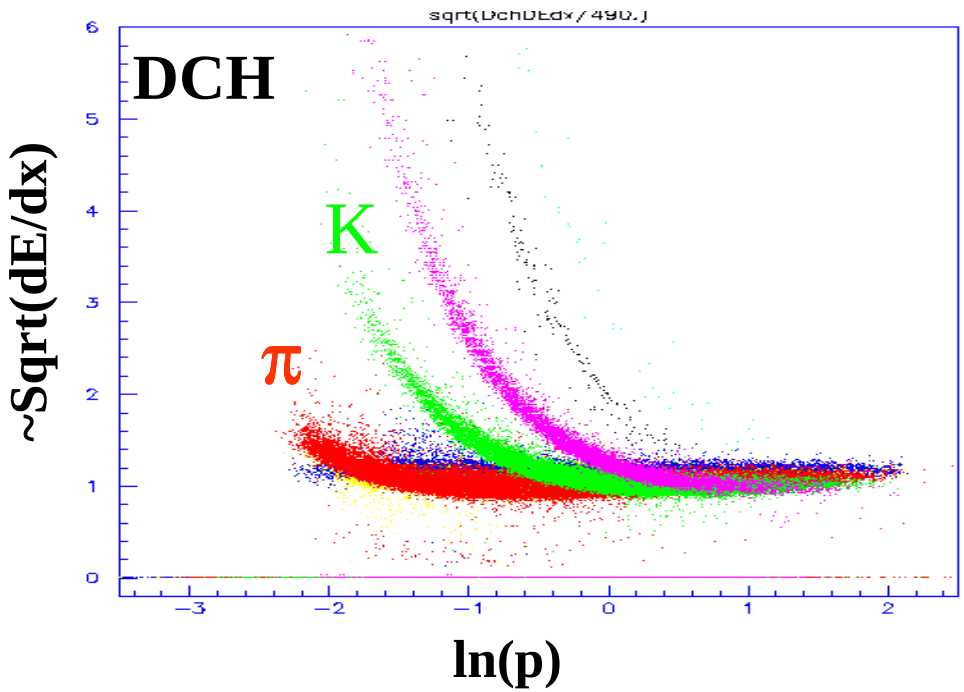


DIRC and combined PID

$$L = L_{svt} * L_{dch} * L_{dirc}$$

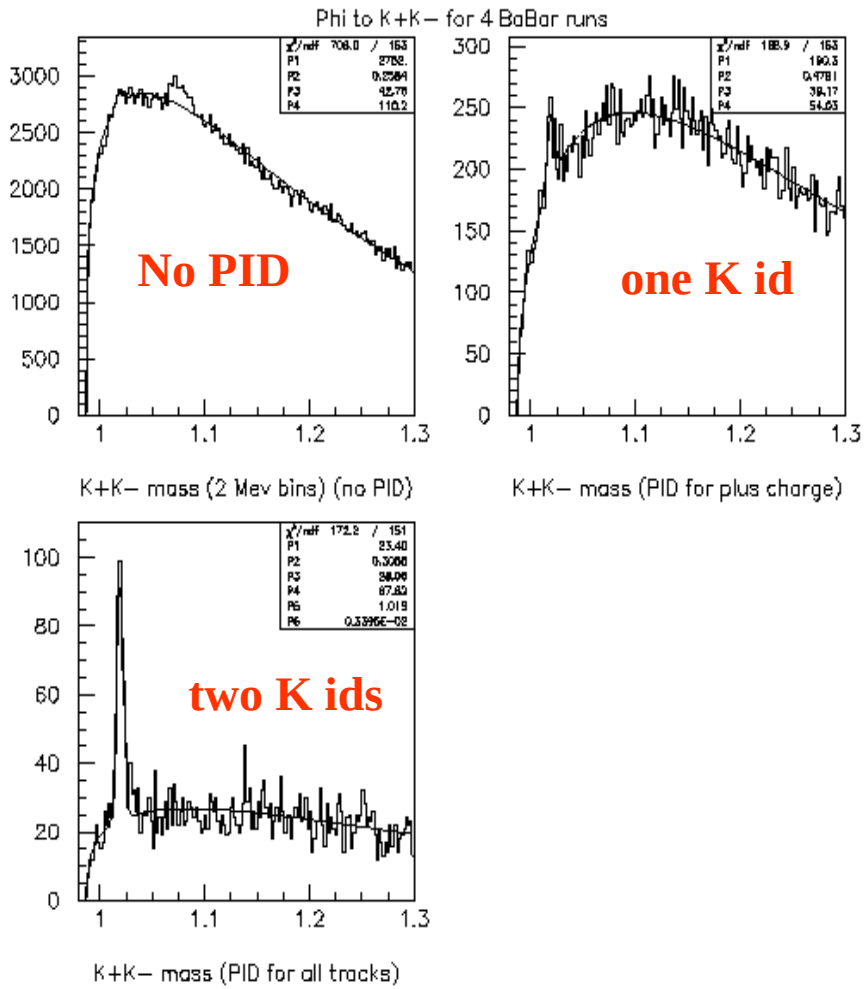




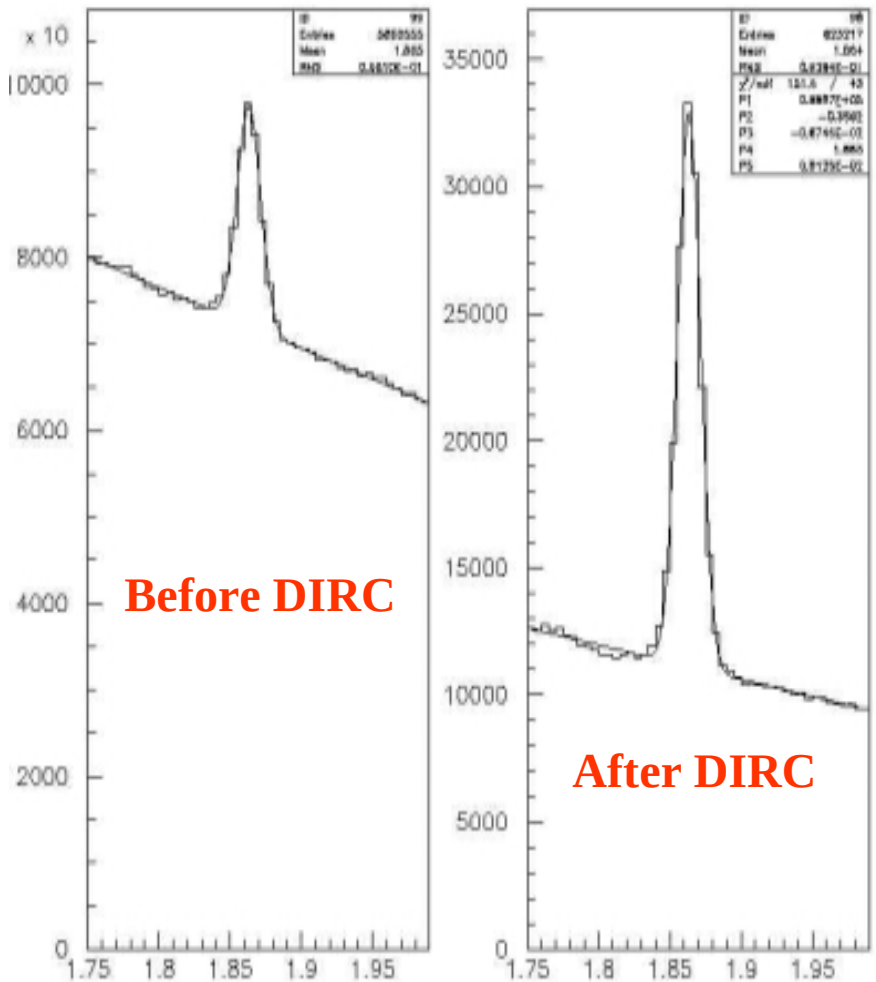


PID impact on physics

$\phi \rightarrow K^+K^-$



$D^0 \rightarrow K^+\pi^-$



Conclusion

- **After 9 month of factory mode datataking one can say that DIRC proved to be a very reliable, easy to operate detector: no major problems, 100% time operational, 99.6% PMTs are alive, very stable timing per channel(jitter *<0.5ns/year*)**

- **performance "per photon" is within 10% of the design, preliminary average performance "per track" expressed in terms of π/K separation is the following: 8.1σ at 2.0 GeV/c, 3.1σ at 3.0 GeV/c and 2.3σ at 4.0 GeV/c. For pions the eff. is ~95% with 2–5% K–to–π fake rates. Improvements are expected from better alignment, more clean control samples with higher statistics.**

- **with PEPII currents being close to their nominal values(LER: 1.0Amp (2.0Amp), HER: 0.6 (0.7Amp)) machine background puts a load on DAQ while having no affect on the reconstruction**

- **DIRC plays a major role in empowering BaBar combined PID, which opens new exciting opportunities for particle physics**